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Ontology-Mediated Historical Data Modeling: Theoretical and Practical Tools for an Integrated Construction of the Past

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Abstract: Building upon the concepts of constructed past theory, this paper introduces the outcome of ontology-mediated data modeling developed by the authors within the last 15 years. Assuming that the past is something constructed through reflection of former times, one of our major concerns is guaranteeing the traceability of the construction process of an integrated historical discourse built from all available sources of information, regardless of their origin or nature. Therefore, by means of defining key concepts such as 'unit of topography' and 'actor', we created an information system for data gathering and exploitation and applied it to some experiences of construction of the past. When applied within the archaeological domain, the result is an archaeological information system interoperable with other sources of historical information. Its strength is that it ensures the traceability of the process from the beginning avoiding the introduction and repetition of errors within the system. Along with the main case example developed in this paper, we also summarize some other data modeling examples within the same conceptual framework.

Keywords: unit of topography; unit of stratigraphy; information system; actor; history; archaeology; database

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1. Introduction

This study addresses some problems and tested solutions—that historians experience when approaching knowledge of the past. According to the principles of constructed past theory, published recently [1], we aim to introduce and discuss the validity of our information system to gather and exploit historical data, and the underpinning concepts of our methodological approach. Our main goal is to strengthen the chances of building the historical discourse on a scientific basis, taking into account the risks of bias and ideological implication concomitant to Social Sciences and Humanities (SSH) and describing our methodology as a measure to mitigate risks.

Indeed, the narration of the past offered by historians—the term is understood here in the broadest possible sense, including archaeologists, palaeographers, anthropologists, philologists, and all scholars dealing with the past in some way at some point of their research—is a construction built from what is left, a collection of remains of different nature and kind. The uncovering of these remains and their articulation within a creative process in no way compromises the ontology of the past itself —that it did happen [2] (pp. 591–592). Therefore, the past is represented, mediated by witnessing or speaking for it in its absence and connecting it with contemporary understanding.

Nowadays, so-called 'digital humanities' offer new ways to develop and disseminate humanistic research. Despite this, their highest interest are the new chances of addressing research in SSH in a brand new way, not only faster, but more effective in terms of data gathering and exploitation, and hence transforming investigation itself by asking new and more complex questions. Incomprehensibly, history as a discipline does not seem to have been the most enthusiastic participant within this digital turn, occasionally encountering endless debates about the usefulness of digital tools themselves. However, some historians are too committed with the reliability and traceability of past construction to disregard the chances digital humanities offer in this domain, even when their digital skills have developed through inquisitiveness and everyday use, instead of a regular training program [3].

The fact is that—beyond the conceptual changes—Digital Humanities actually made us face a change of paradigm in the processes of historical research in which:

- Available tools allow us to deal with massive datasets, some of which were disregarded until recently as marginal or non-significant.
- Interdisciplinary teamwork is key to build a richer, fairer and more precise construction of the past.
- Information sources of diverse origin and nature must be integrated within a cross-disciplinary perspective.
- Open datasets become compulsory within a new research Open Science framework.

All these new scenarios require new management of information fluxes claiming for the theoretical definition and practical development of information systems for a safe and efficient information management and research good practices. According to the main research developed in recent years and summarized in the following section, our main goal within this paper is to propose a specific ontology-mediated data modeling and a research information system (RIS) built accordingly. Regardless of the origin or nature of information sources susceptible of being considered as a vestige or a reflection [1] (p. 14) of the past, it is possible to exploit them within a shared code, and so we aim at offering our conceptual proposal and some examples of successful application. One of these examples, is the successful implementation of an Archaeological application of the Research Information System (ARIS), called SigArq.

2. State-of-the-Art: Constructed Past Theory and Theoretical Approaches from Archaeology and Record Management

Thibodeau's Constructed Past Theory (CPT) [1] has shed new light in the conceptualization of past construction, which is not new particularly in archaeological theory, where material vestiges never speak by themselves, but it is the archaeologist that must give them their significance [4,5]. Figure 1 provides a summary synthesis of CPT, wherein the Constructed Past is the final product of a process in which a Target Past evolves during the In-Progress Construction process according to the Intentional Domain. This comprises the Intent of Construction and the Sphere of Interest, both classes being determined by the researcher.

Intent of Construction and Sphere of Interest are interdependent classes, as the first shapes the process and its results and the second specifies the period under investigation and what is of interest. Therefore, the final construction of the past should satisfy the intent of construction and be about the sphere of interest. Four subclasses are involved within the Sphere of Interest: Entity, Event, Process, and State of Affairs. An 'Entity' is something, whether conceptual or physical, that existed and that had, at least, one inherent and persistent property. An Event, in contrast, is a change in an Entity. What changes and the nature of the change are two defining properties of the Event. Several events aggregated as steps may define a Process. Finally, Thibodeau defined the State of Affairs as a set of one or more assertions, all of which are true for the same chronological period and concern the same or related objects that are either instances of the Entity, Event, or Relationship, or their subclasses.

Entities and Events have an Involvement relationship—also expressed as a class—including four subclasses: Participant, Observer, Altered, and Instrument, according to the nature of the change occurred to the Entity during the Event. When human action gets into the scene, it introduces a subclass of Event: Action. Thus, Action is an Event in which human beings have an active role as participants.

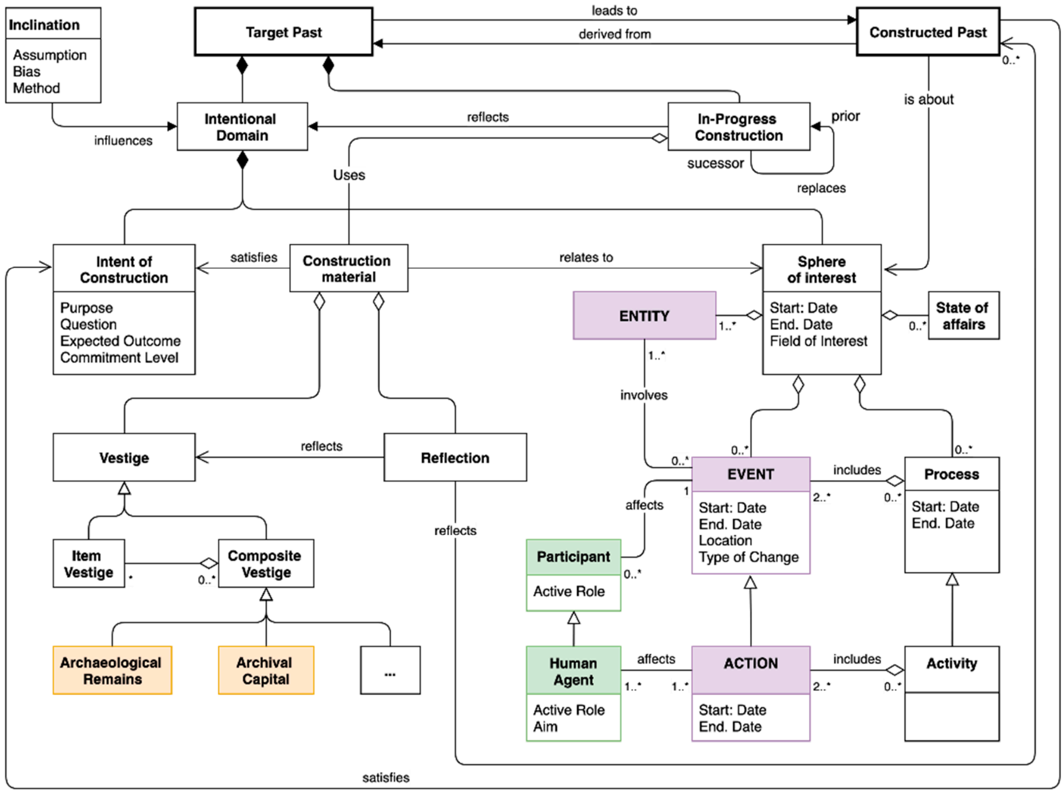

Figure 1. Summary view of Constructed Past Theory (CPT) according to K. Thibodeau [1] expressed as a UML diagram. Highlighted classes in purple and green are those related to our concepts of 'Units of Topography' and 'Actors', respectively, as further developed in our research domain. Extra detail will be provided in Section 3. Classes highlighted in orange are those in which these conceptual modeling has been applied.

The Involvement relationship between Entity and Event and the role of humans in between is particularly interesting to us because our recent research on ontology-mediated data modeling fits really well in Thibodeau's CPT as a practical case and proposal for further development, as we will demonstrate in forthcoming sections. Any In-Progress Construction of the past under a determined Intentional Domain uses Construction Materials that might be—Item or Composite, Vestiges or Reflections. Vestiges are objects that existed in the past and survive the time of the sphere of interest, and Reflections are information objects produced in the course of construction. Being archaeologists ourselves, we have been deeply concerned with the selection and use of vestiges within Historical Science, as material archaeological evidence has sometimes been disregarded in favour of Archival Capital or written sources in general. Fortunately, recent times have fruitfully changed this perception, particularly for the medieval and post-medieval period. Medieval archaeology—especially under the methodological perspective of landscape archaeology—has contributed to the material turn [6] in Archaeology, Anthopology, History, and other past-constructing disciplines, even though this turn has not always been exempt of debate [7–9].

Apart from Thibodeau's recent abstract approach—as stated by the author [1] (p. 16)—few references address the problem of 'managing information' in practical terms in order to build an integrated historical discourse dealing at once with sources of information from many different origins and supports [10–12]. Some of them are still highly theoretical [11] or archaeology-based [12], and, frequently, specific research about ontology-based data management only addresses historical problems tangentially [13,14]. Indeed, we are indebted to the archaeological theory and practice in the development of our data modeling, particularly regarding landscape archaeology [15–17]. Recently, considerable efforts have been made in order to develop common standards to ease data exploitation, and to empower digital research in the fields of History, Language Studies, Cultural Heritage, Archaeology, and related fields in the domain of Social Sciences and Humanities (SSH). The already completed PARTHENOS project [18] was a beautiful example of them, and it hosted an archaeological experience of research infrastructure implementation called ARIADNE [19]. Through this archaeological data-standardization-based project and other subsequent experiences, the archaeological domain has developed data integration practices through metadata introduction by means of controlled vocabularies.

Despite this, most of these experiences, particularly in the archaeological discipline, tackle with data standardization in order to make the results of research exchangeable under FAIR conditions, but very few suggestions are provided in order to deal with the FAIR character of basic research itself. Before reaching exportable results, Historians in general and Archaeologists in particular are file generators and our aim is to introduce and share the way in which we deal with the records produced since the very beginning of our research until the final product or report is obtained. Hence, the Research Information System (RIS) introduced below in this paper and its practical cases are part of an interdisciplinary proposal built upon the basis of Records Management [20,21] and Conceptual Modeling [22]. Our RIS proposal and its practical application through the SigArq ARIS can be used as a domain solution or an example of International Research on Permanent Authentic Records in Electronic Systems (InterPARES). Actually, most of the design of the system and its File Management Classification Chart as a result of identifying research processes and giving response to them follow the InterPARES methodological approach [23] (pp. 6–7). A. Mauri [24,25] set the conceptual basis of our Research Information System (RIS) as part of his MSc and PhD dissertations and applied it to the study of the County of Barcelona in the Early Medieval Period [25] (pp. 103–384). Although some experiences in historical data management and computing have been known since 2005 [26,27], most of them deal almost exclusively with written evidence while data integration experiences through interoperable minimum information units are rare. Mauri's study [25] built an integrated construction of the past for the first time, gathering information from different sources regardless of their origin or nature. The concepts of 'Unit of Topography' (UT) and 'Actor' (Ac) were defined then as minimal 'Units of Information' (UI) of historical knowledge and the RIS were built accordingly [28]. Further crosscutting research used those information units at the basis of archaeological data management in connection with E. C. Harris' concept 'Unit of Stratigraphy' (US), and P. Del Fresno conceptualized the main structure of his Archaeological Research Information System (ARIS) [29,30] as advanced development of the original RIS. More recently, the concepts of UT and Ac were applied to mercantile accounting books from the 15th Century AD and the RIS was improved [31,32].

More than 20 years after its first conceptualization, now we are in a good position to review the system structure and to offer—through different examples—a more complete and tested proposal according to its underpinning concepts and ontology. In the following Sections 3 and 4, the main concepts are defined, their relationships established, and the software applications described. Anyway, our RIS is still a tool in construction and our contribution aims at exchanging our thoughts and perceptions with other researchers as well, in order to build a better and even more functional information system.

3. Underpinning Ontological Concepts and Data Modeling: The Methodological Basis of RIS

3.1. Definition of Minimum Information Units: Conceptual Data Modeling

The minimal UI defined as Unit of Topography (UT) and Actor (Ac) are identifiable and exploitable from any vestige of the past regardless their origin or nature. If understanding—as Thibodeau did in his CPT [1] (p. 13), and we do in our RIS—that any vestige or reflection of the past is susceptible to be considered as raw material for past construction, the dichotomy between archaeology and history—material and written sources—disappears. So do any other differences between information sources such as ethnography, geography, iconography, and many others. In fact, two key interdependent concepts to identify historical information are time and change, and any vestige or reflection able to inform about those is indeed a source for building historical knowledge.

Scholars have probably not paid particular attention to the idea of Time as an ontological concept, probably because of the confusion between time and chronology or succession of facts, or maybe because of the consideration of time as an absolute and independent magnitude that acts as a container of events and entities. Time understood as such has been revealed as an insufficient and useless concept. The goal of historical research—or Past Construction—is to identify and describe a sum of environmental, ecological, economic, social, cultural, political or whatsoever factors that challenge and shape human life within a determined period of time (Sphere of Interest). By means of this characterization of factors, historians aim at defining models to detect and measure permanence in front of change. This rhythm or cadence between what happens before and what comes later is what we understand as Historical Time [33].

Accordingly, our proposal is to identify the information components of any vestige as a single and unique unit informing about entities, or events—in Thibodeau's terms [1] (pp. 7–9)—or both, and their relations or values. Figure 2 summarizes our data modeling in relation with Constructed Past Theory as a ULM diagram. Vestiges or reflections of the past can inform about facts, those who performed, witnessed or suffered these facts, the mechanisms making them happen, and the time and place in which they occurred. Each one of these elements is represented as a vestige's component. The facts themselves (Units of Topography) are something that existed—entities—or something that happened—events. Both elements took place in a determined place and time, regardless of the fact that these spatiotemporal coordinates are known or unknown to future generations. Therefore, the main components of vestiges are defined as follows:

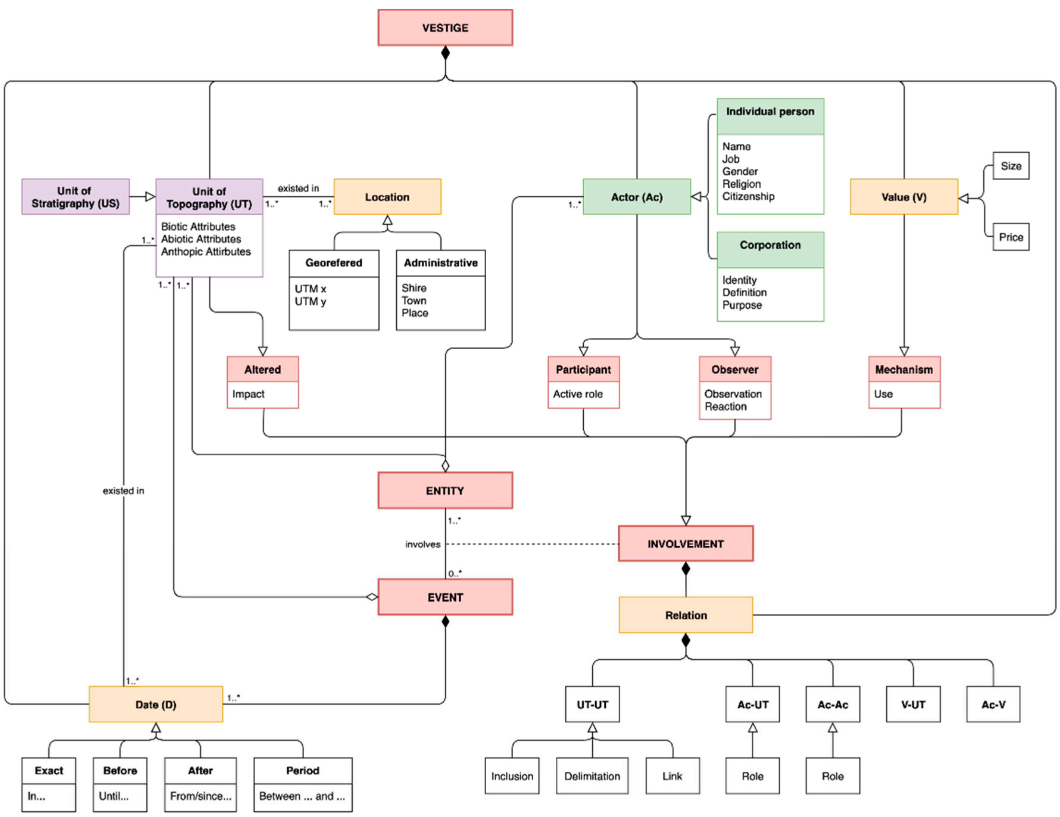

Figure 2. UML diagram expressing the minimum information units of historical knowledge as components of Vestige. This conceptual modeling fits well within Thibodeau's CPT, whose classes are highlighted in red. Our further concept development is highlighted in purple for UT, green for Ac and orange for relational classes.

- **Unit of Topography (UT)**: It is the evidence of an action or situation that can be located in space and time, regardless of the specificity of the information source and its biotic, non-biotic or anthropic origin. Each UT has a specific location and date. Location can be expressed as a UTM coordinate or as an administrative delimitation that might have changed during history. Some UT examples are the existence of a vegetal specimen in a determined area; the consecration of a church; the transaction of a property; the existence of a necropolis; the remains of a pathway, a birth, a marriage, a death or a burial, etc.
- **Actor (Ac)**: It is the individual or corporative, active or passive, protagonist of an action identified as a UT. If being an individual, their attributes are their name, gender, religion, citizenship, date of birth and death, etc. Different individual actors gathered for a given period of time with a particular purpose and under determined conditions can act as corporative actors. In CPT's terms, Actors should be considered Entities, while UTs could be Entities or Events.
- **Value (V)**: Expressed as a price or a size magnitude, it is a mechanism. Through the value of something, the Actor makes the UT possible.
- **Date (D)**: It is the specific time when the event happened. If the entity is related to permanence and the event relates to change, at least one entity has to be involved in an event [1] (p. 7), and date is a component of an event or a process. We can identify as a date an exact point in time, a period before an exact point or after it, or a period between two exact points.

The way an Entity is involved in an Event is specified in an association class called Involvement in CPT [1] (p. 8). We might feel more comfortable with the term 'Relationship' here, in order not to interpret a priori any (active or passive) kind of involvement. Different possible relationships between UT, Ac or V are expressed as components of the involvement. These are:

- **UT–UT**: A UT can include, link or delimitate another UT. Hence, Inclusion, Delimitation, and Link are classes of the UT–UT relationship.
- **Ac–UT**: This relationship is expressed as the active/passive role the Actor plays within a UT.
- **Ac–Ac**: Any familial, political, social or economic relationship identified between actors is a condition for events to happen and entities to transform. Through this relationship, individual actors can join into corporative actors forming then new entities.
- **Va–UT**: This relation expresses the price or size of a UT.
- **Ac–Va**: The use of this value by the actor—as expressed in this class of relationship—is the mechanism to create a new UT.

This conceptual data modeling is applicable to any kind of historical source regardless of its origin, but the nature of sources and the specific methods of each social science require minor tool adaptation. Text labeling is a useful tool for data gathering in written vestiges. A few examples of text labeling and table edition in Appendix A offer practical application of data gathering from archival capital. Datasets are then collected as tables in interoperable databases built according to the sphere of interest of specific research projects. The main database structure includes UT (Table A1) and Ac (Table A2) related tables as its main components, though research objectives might require other related tables such as Values or Relation (Table A3). Regardless of the number of tables within the database, data must always be stored in such form, placing variables in columns and observations in files, according to a tidy data structure [34]. Graphic, iconographic, or audiovisual material might require other UT/Ac-identification techniques so that the degree of table completion might be lower, but data identification and gathering follows the same system, as demonstrated with examples in Appendix B.

Dealing with material vestiges requires the appropriate excavation and recording methods of archaeological science. Nowadays, the most extended and accepted archaeological method is the stratigraphic extensive excavation proposed by E. C. Harris [35], where the 'Unit of Stratigraphy' (US) is the minimal UI. Our concept of UT owes much to Harris' stratigraphic approach, since UT and US are comparable and interoperable units, as we will explore more deeply in the discussion section.

The application of our RIS to the Archaeological domain and the creation of SigArq is one major achievement shown in the results section below.

3.2. Units of Topography and Units of Stratigraphy: Towards an Archaeological RIS

The final stage of archaeological fieldwork is the production of a report or the publication of a paper that will hopefully be integrated in the Construction of the Past. As the so-called material [36–39] and spatial turns [40–43] develop in Historical Science, data integration, and the search for a common and shared exploitation code is a much-needed strategy.

Different procedures for data gathering according to the specificity of the vestige must lead unavoidably to a common exchangeable information unit, as illustrated in Figure 3. Our research explored how to connect a long-term accepted archaeological concept—Unit of Stratigraphy—to data obtained from other vestiges and reflections, and how to deal with the significant difference between them regarding their materiality or immateriality.

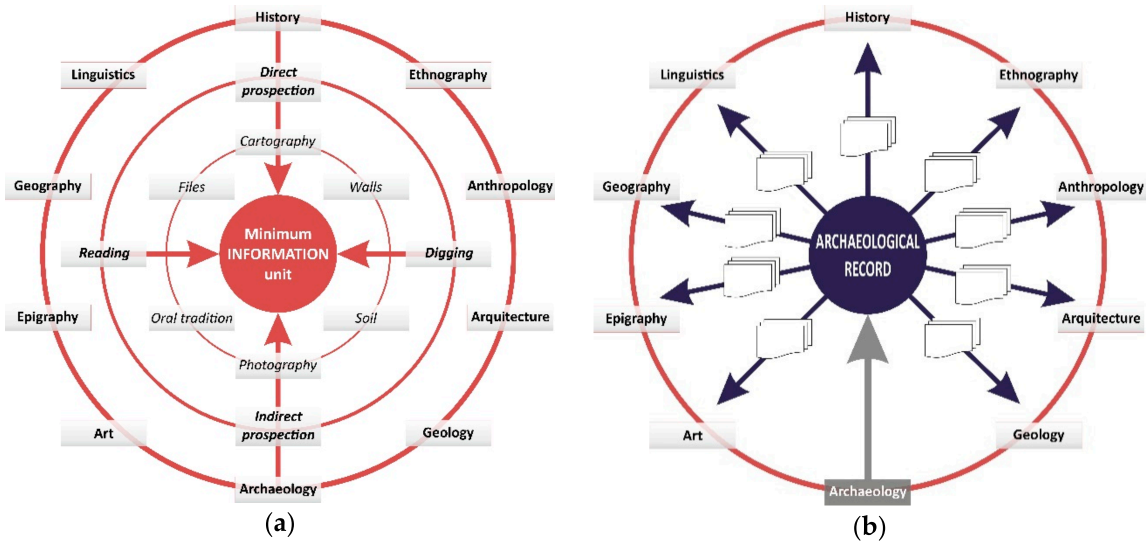

Figure 3. Exchangeable information management scheme. Different disciplines—regardless of whether they share the SSH domain or not—have their own research methods, which are comparable as long as they share minimum information units (**a**). When this happens, a new interdisciplinary scenario allows the common use and exploitation of both vestiges and reflections according to archaeology (**b**).

As defined by E. C. Harris, archaeological US represent an archaeological aspect of the cycle of time. They are of universal character and can be found on any archaeological site in the world [35] (p. 42). Despite the fact that all US could be considered as UT accordingly, a matter of scale needs to be solved in order to guarantee interoperability between archaeological record and archival capital. Material vestiges such as postholes or burials include several US each and, in that case, it is not operational to consider every single US as a UT. The answer to the problem is provided by A. Carandini's definition of "Activities and Phases" [44] (p. 143) as groups of US and groups of activities respectively. UT recorded from archival capital can have a material equivalent in activities or phases of an archaeological site, and determining this correlation is a collaborative task of archaeologists and historians. Figure 4 shows an example of this US–UT correlation in a landscape analysis of agricultural activities.

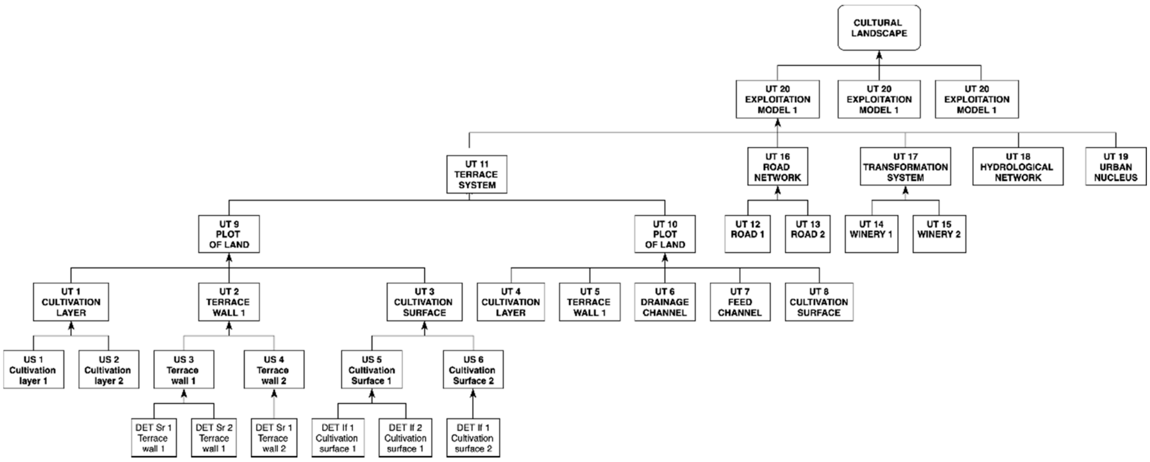

Figure 4. Model of integrated information that illustrates US–UT correlation. Notice that bottom level includes a subclass of US registered as details of the US. Although further thoughts on this will be provided in the discussion section, each row in the graphic represents a same-scale zoom on landscape analysis and how different US are part of the material vestige of a single UT.

This conceptual data modeling is permanently under development, but the definition of its main architectural structure led us to put into practice some fruitful research experiences through GIS tool-development and data exploitation. The underpinning idea of the RIS is that data gathering needs to be monitored and records must to be built under normalized codes in order to ensure interoperability and interdisciplinarity in the SSH domain. The archaeological RIS SigArq [45] is a clear example of this data integration and management.

4. Results: Experiences of Past Construction and Tool Development

Data gathering and exploitation according to the use of UT and Ac as minimal units of information linked though values and relationships led to a more precise knowledge of the County of Barcelona [25]. Past Constructed under those principles was generally accepted as a reflection—in Thibodeau's terms [1] (p. 14)—and used in further research [10,29,46]. Research developed in this framework particularly reflects the chances of data integration from written sources, ethnographic approaches, field archaeology, and material sciences [47] (pp. 125–129,143).

Nevertheless, the most complete application of our methodological approach is the conceptualization and development of the Archaeological RIS SigArq, although some other experiences are currently under construction [31,32]. Figure 5 shows the general design of this ARIS as a system of subsystems in which different existing computing tools are independent, interconnected, and distributed along its architectural levels. All these devices are concomitant to the ARIS as long as they support a transversal management of the heritage, concerning both their agents and subjects. The ARIS is obviously web-supported and allows all subsystems to be interconnected.

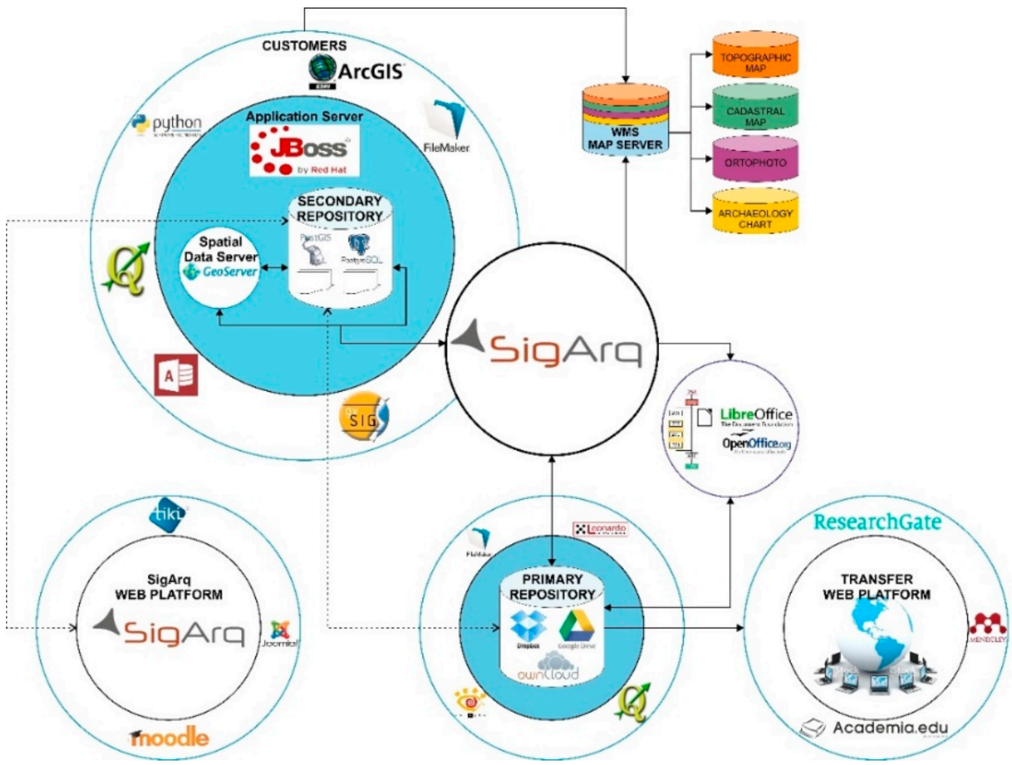

Figure 5. General design of SigArq ARIS as a system of subsystems. Different software can address and exploit text, graphic, cartographic, and relational data contained in linked repositories in order to produce reports and files used as a reflection of Constructed Past.

In order to make this interconnection possible and according to the integration of archaeological record within the principles of Records Management [48,49], the documentation and analysis of vestiges follow a normalized protocol of data collection summarized in a file classification chart. These are supported within SigArq Geographic Information System, which allows researchers to gather all informative dimensions of US in one single database.

4.1. Archaeological Information System: Classification Chart as File Management Tool

Building the archaeological record according to the principles of Records Management implies identifying the main processes in research from the creation of the file production context until the delivery of the final report attesting the research project completion, as suggested by the InterPARES's methodological approach [23] (pp. 6–7). These processes originate items which are ordered and hierarchized in files and series accordingly. Building the archaeological record, in particular, produces several files that are representative of the different dimensions of US as a minimal information unit. These dimensions are:

- **Descriptive dimension**: US description includes information about its class (deposit, structure or interface), definition (e.g., layer, wall, hole, etc.), natural or anthropic origin, and interpretation (e.g., construction, destruction, use, erosion).
- **Graphic dimension**: Photographic register records the graphic dimension of US through different pictures (aerial, general, detail) that are stored and identified through normalized metadata.
- **Cartographic dimension**: As stated in archaeological method, a single-layer plan for every US records the basic cartographic data by means of drawing the boundary contours of the US, and placing some evenly distributed elevations on the plotted area [35] (pp. 95–104).
- **Temporal dimension**: Defining the stratigraphic sequence is the way to record the temporal dimension of the US, according to the physical relation between them [35] (pp. 34–39).

These four dimensions are part of the raw data gathering included in the first of the processes –building the archaeological record—as shown in Figure 6. Defining the methodological work processes precisely leads the researcher through the project management and execution through different activities, series, and composite files [50], according to the classification chart shared by the authors and their team.

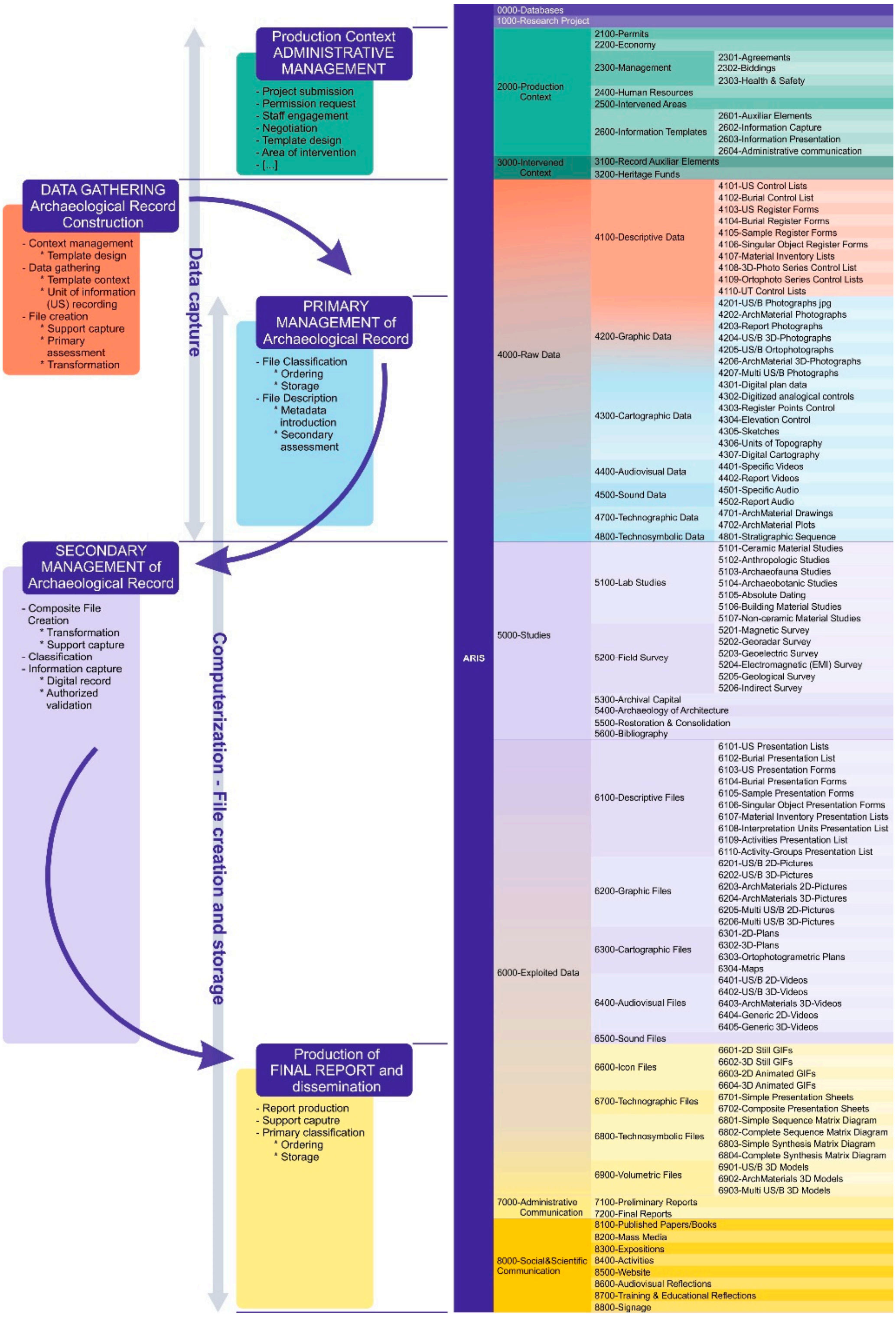

Figure 6. Classification chart of series, folders and files of the ARIS according to the main diagnosed processes of information management.

Data gathering is the first step of the research process. Each US is recorded according to its four dimensions (descriptive, graphic, cartographic, and temporal) by means of filling a registration form, taking some pictures, drawing its plan and recording the physical relation between different units. During this process, primary assessment of data takes place, as researchers select the correct and valid data that will get into the system. Primary management of the archaeological record consists in a two-step procedure: file classification and storage, and file description. The first step demands naming each item file according to the composite file or series it belongs to. Table 1 shows this normalized form. Classified and stored files are then described through metadata introduction. Metadata include general information such as site identification, fieldwork campaign, authorship, or origin; specific data as trench identification and US number; and finally that information coming out from secondary assessment. Through this secondary assessment, researchers will select those files that better represent the US four dimensions and the next step—secondary management of archaeological record—will start.

Table 1. Primary management of archaeological record. Item file classification and storage.

ARIS			
Function	**Activity**	**File**	**Item**
4000-Raw Data	4200-Graphic Data	4201-US/B Photographs .jpg 4202-ArchMaterial Photographs 4203-Report Photographs [. . .]	4201-XXXAAAA-000N.FFF [1] 4202-XXXAAAA-000N.FFF 4203-XXXAAAA-000N.FFF [. . .]

Where: 4201 is a unique correlative number to identify the composite file within the folder; - XXXAAAA is an expression of the site (XXX) and year of campaign (AAAA); - 000N is a sequential numeration for each simple file within the composite file; - FFF is the normalized expression of file digital format (Example: 4201-SGR2014-0001.JPG identifies the first US field picture taken in Sant Genís de Rocafort (Martorell, Barcelona) during the fieldwork season in 2014.)

Secondary management is where data exploitation and interpretation takes place. Specific lab studies of archaeological materials, field survey results, exploitation of archival capital according to the UT/Ac identification and register, archaeology of architecture, and heritage preservation are interdisciplinary approaches that have a specific place within the ARIS structure. This will lead to the creation of documents that will be an integral part of the reflections presented as the final report. Within this research system, SigArq is—properly speaking—a web-supported platform built upon GIS software that allows us to gather and exploit data within a single application, and—what is more relevant—that monitors data introduction into the system in order to avoid inner contradictions and minimize errors. This is possible by means of using normalized thesauri and leading the user through the entire process according to the theoretical management of information established in the classification chart.

4.2. GIS and Archaeology. SigArq Tool Development

Nowadays, SigArq is an application still in transformation. It currently allows researchers to incorporate and manage excavation primary record, exploit these data and generate preliminary and final reports. Archaeological material databases are part of the ARIS but are not included in the application, since it currently is a GIS-based software. Data introduction takes five correlative steps that must be completed in order. Users are not allowed to skip any of these, as this would jeopardize the quality of the final record. These steps are:

1. **US definition**: US identification requires briefly defining what it is/was according to the materiality of the remains. A few examples of short definition are wall, filling, levelling layer, silo, pit, landslide, tomb, individual within a burial, etc.
2. **Form Completion**: Once the US is identified and defined, users are allowed to record US descriptive and temporal dimensions within a form. Although Description, Composition, and Interpretation are free-text entry input fields, fundamental attributes such as Origin or Type of

US amongst others are single-choice input fields controlled through thesauri. Within the US form, the temporal dimension is introduced by means of recording the physical relation between the US under examination and those below. System crosscheck returns the relations with the US above and verifies the non-existence of contradictions in the stratigraphic sequence through a green-shaded status field. If contradictory data are introduced, they will be highlighted in red.

3. **File uploading**: General and detailed pictures of each US, identified with metadata—as shown in Table 2—and stored in the adequate ARIS-series, attest the US graphic dimension. In this step, one selected picture file is uploaded into the application together with an XYZ-coordinate capture table.
4. **Cartography production**: The cartographic dimension is the last item recorded within the system. The previously uploaded XYZ-table is now used to produce the plan and elevation, reproducing the cartography of the US within the general excavation plan.
5. **US Metrics and exploitation**: Like any SIG software, SigArq has some enabled geometric functions that calculate US total surface, point out distance and any other metrics desired for exploitation.

Table 2. File description and secondary assessment through metadata introduction [1].

Group	Field	Character [2]		Indications for Users and Format
Legend	Title	O		Picture caption describing the content: <text>
	Special instructions	O		Instructions for further processing or considerations to take into account (e.g., labeling mistakes if any): <text>
Key words	Key words	C	G	Archaeological site ID expression: <AAA>
		C	G	Year of fieldwork campaign: <0000>
		C	G	Trench: <III>
		C	S	US ID number: <US0000>
		C	S	Burial ID number: <B000>
		C	SA	For pictures with plan indications: <photopla>
		C	SA	For drone-obtained aerial views: <photodrone>
		C	SA	For SigArq uploading (one per US): <photoSig>
		C	SA	[. . .]
Credits	Author	O		<Surname(s), Name>; <ORCID>
	Origin	C	G	<Institution or Company Name>
	Copyright	C	G	CC (by-nc-sa)
	Contact	C	G	<e-mail address>
Date/Time	Creation date	C	G	<yyyy/mm/dd>
Origin	City	C	G	<City name>
	Location	C	G	<Location name>
	State/province	C	G	<State/province name>
	Country	C	G	<Country name>

[1] Metadata schema shown in this table follows the normalized IPTC by XnView open software; [2] *Character* indicates whether the metadata are of compulsory (C) or optional (O) introduction, and the specific character of the compulsory descriptive information contained: General (G), Specific (S) or referred to Secondary Assessment (SA).

To sum up, archaeologists can interrogate all US dimensions in one single screen—as shown in Figure 7—after the record process is completed, and data are compared to the entire US assemblage for archaeological interpretation. These data being available from other software and platforms represented in Figure 5 above, data loading in previously designed templates produces US tables, Harris-Matrix diagrams and final reports easily and efficiently. The controlled process of data introduction ensures the quality and the traceability of the entire process. The result is a FAIR (findable, accessible, interoperable, and reusable) archaeological research, as claimed recently by European stakeholders [51].

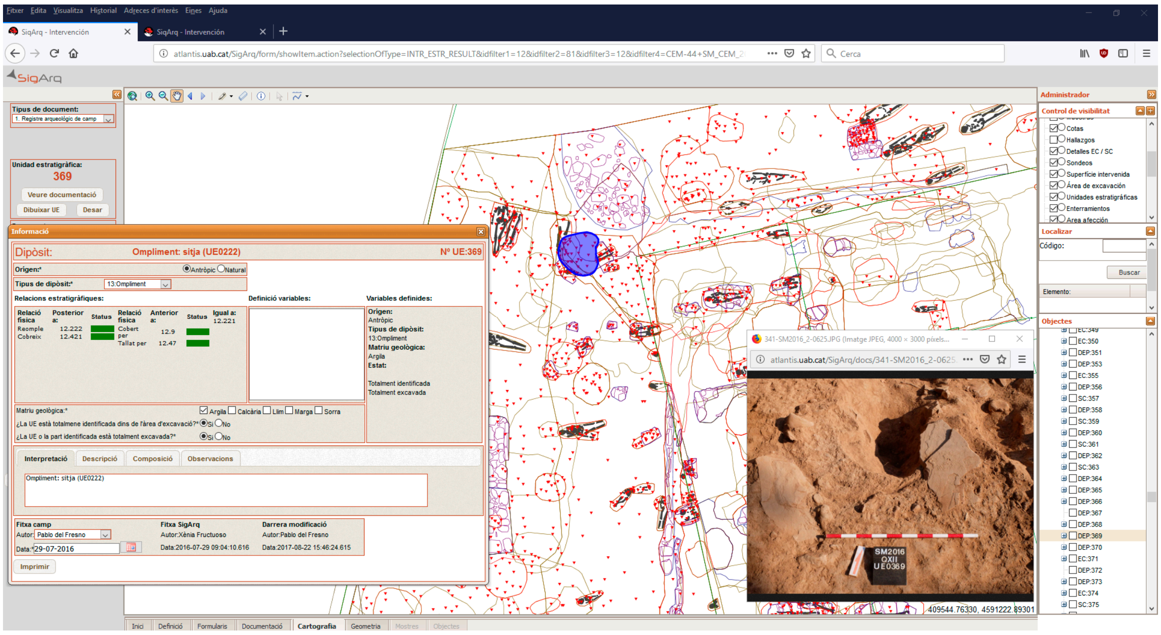

Figure 7. SigArq screen-view. At the end of the data recording process—as per US 369 in this figure—all four informative dimensions can be displayed at once for further exploitation.

5. Discussion: Past Construction through UT/US Dialectics

We have shown the building architecture of our ARIS and derived software application SigArq as a practical case of Research Information Systems for past construction. Still, we should discuss further implications of UT and US information units bearing in mind that SigArq is a US-built software according to Harris' principles of archaeological stratigraphy [35]. It is worth insisting in the main issue to solve when combining archaeological data and information gathered from any other source: the need to define a common and exchangeable unit of information. As pointed out in Section 3, we can consider all US as UT. Despite this, the existence of four informative (descriptive, graphic, cartographic, and temporal) dimensions of a US is an ontological requirement for them to be, while UT can exist regardless of their materiality or the lack of it. From the ontological perspective, the UT exists as far as there is a vestige or reflection of the past informing about it, while the US needs the existence of an archaeological context.

Our contribution to an Integrated Construction of the Past lies upon the fact that, as far as—as archaeologists—we are in need of other sources of information for an accurate interpretation of material data, we have developed a code valid for Reflection construction with independence from the source. To that extent, UT/US reliability has to be evaluated, and the SigArq application contributes to monitoring the process of data gathering and exploitation in order to ensure its quality based upon rigorous and FAIR data collection, storage, and exploitation. This is ensured by the inclusion and use of standardized metadata for any single file produced during the research process, and it is guaranteed by the use of shareable platforms as those shown in Figure 5 [52].

Ontological differences between UT and US have to be considered, even though these do never compromise unit interoperability. Both of them are Units of Information (UI), data, evidences of the recent or remote past, for which a spatiotemporal context has to be provided in a precise or generic way. Place and time are essential ontological attributes in all cases regardless of the origin of the source—vestige or reflection—its materiality, the scientific discipline that produces it, the methodological specificities of data gathering, or the reliability of the information [29] (pp. 65–75). Table 3 summarizes the main differences and similarities between UT and US, which are mostly related to their materiality, and the possible relations with other UI for past construction such as Actors or Values, defined above.

Table 3. Units of information (US/UT) ontological summary.

Attribute	US	UT
Source of obtention	Material	Written, material, visual, sound
Materiality	Essential	Non-essential
Informative dimensions:		
• SPATIAL	Essential	Essential
• Descriptive	Essential	Essential
• Graphic	Essential	Non-essential
• Cartographic	Essential	Non-essential
• TEMPORAL	Essential	Essential
Possible relations:		
• US-US/UT-UT	Physical contact	Inclusion, delimitation, link
• Ac-US/Ac-UT	Non-possible [1]	Non-essential
• US-UT	US = UT US + US = UT	US = UT UT + UT = UT
Involvement in event	Essential (altered)	Non-essential

[1] The material register does not inform about Ac.

As such UI, they are fully comparable, and together they shape the past construction. Their main difference is their materiality—essential for a US to be—and the consequences materiality has for the data gathering process. Other differences are concomitant to the relations that UT/US might or might not establish between them or with other UI. As stated in Section 3, the dichotomy between UT and US is a matter of scale and inclusion. US cannot include other US inside, but they can sum. The addition of US turns into a new unit of information originated as a reflection, and, therefore, it will necessarily be a UT. The interpretation process of material evidence leads unavoidably to the grouping of different US in Activities, Groups of Activities, or Phases according to the events occurred within a site identifiable through the archaeological record. Although we are content to use the terms proposed by A. Carandini [44] (p. 143) here, in the new scenario proposed, Activities, Groups of Activities, and Phases are equivalent to UT anyway.

These, registered from many other sources of information, can appear within every grade of this interpretational hierarchy of the archaeological record. Past construction then becomes completely interoperable and urgently interdisciplinary. As equivalent and comparable units, UT and US are part of the well-known Harris' matrix diagram [35] (pp. 34–39) and, when exploited from knowledge bases, could be analyzed, exploited, and represented in terms of knowledge graph technology [53,54]. If considering, as L. Ehrlinger and W. Wöess did [55] (p. 3), that the Knowledge Graph acquires and integrates information into an ontology and applies a reasoner to derive new knowledge, the potential of our ontology-mediated data modeling could significantly increase.

The link between archaeology and other SSH, History in particular, is in no way unidirectional. Examples of UT identification from graphic vestiges (e.g., drawings or photographs) are fundamental for the interpretation of the archaeological record. Certainly, ancient photographs or other reflections —an archaeological diary with drawings made 40 or 50 years ago about a site no longer available for excavation—might inform about the material evidence of an action, regardless of whether an updated archaeological record according to the four dimensions of US is possible or not. This is demonstrated by UT identified in examples provided in Appendix B [56] (p. 154, Figure 4), as they offered a good correlation with the archaeological register built several decades after the pictures or notes were taken [57] (p. 147, Figure 3).

Finally, getting back to Thibodeau's CPT, US as entities have one unique and specific class of involvement in events, which is Altered, since they are the material evidence—result or impact—of those events. Thibodeau's distinction between Action and Event, being the first a specific class of the second, is considered as such in SigArq's US record as well. The US description form considers their natural or anthropic origin as an attribute. Hence, the human character of an Actor's role is attested even though it is impossible to identify it as a UI in the fieldwork. US of natural origin are then vestiges informing about events, and US of anthropic origin are the material evidence of actions.

6. Future Prospective

As long as this is an on-going project, we would like to outline the future potential and prospective of this approach instead of a set of fast-changing conclusions. In the framework of the so-called Digital Humanities, the chances offered by ICT for an integrated historical discourse have been our major concern for many years. Consequently, we designed a Research Information System built upon ontology-mediated data modeling. Throughout this paper, we summarized a methodological proposal for Past Construction in accordance with our perceptions of how historical discourses are originated and our scientific experience as archaeologists and historians, which we consider two inseparable categories of past-constructing scientists. The archaeological development of this research information system is an ARIS currently in use at different archaeological sites in Spain. The SigArq application as a quality-monitoring tool for data gathering and exploitation is a concomitant improvement towards the creation of 'FAIRer' reflections of constructed past.

Our self-awareness of being file generators when fulfilling our archaeological duties led us to search the principles for file classification and preservation in Records Management, in an effort to ensure the backwards traceability of research processes as one of the underpinning elements of scientific reliability. The definition of RIS in Historical Science requires another key element for making interdisciplinary collaboration possible: the use of a common and exchangeable code. Thus, we introduce our conceptualization of UT as a main Unit of Information obtainable from many different domains and sources, regardless of their vestige or reflection character and the nature of the science that provided them. This provides a shareable language for different domains in SSH focused in integrated Past Construction. The key advantage in using these UT and Ac concepts is that the problem of traditional fragmentation of SSH could be solved to some extent. The archaeological initiative of our data-modeling is also due to the high level of fragmentation of archaeological data and the traditionally limited capability for the collaborative research across boundaries, as already diagnosed the ARIADNE project's partners [19] (p. 2).

Thibodeau's CPT, as a germinal articulation of a challenging theoretical framework for past construction, moved us to review our in-progress data systematization and ontology creation. Precisely because the past is far more complex than what can be represented in any diagram [1] (p. 19), ontology-mediated data modeling revealed useful in interdisciplinary past constructions generated by the authors and their colleagues, but it needs a permanent revision of ontologies and terms in order to achieve a terminological consensus. It is time for SSH to get hands on past construction building reflections from an integrated perspective, taking advantage from electronic-supported devices, using ICT as a requirement for more ambitious research aims in History, and making Digital Humanities a term which becomes meaningful for Historical Science.

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Appendix A

The following examples illustrate data identification and labeling of Units of Topography (UT), Actors (Ac), Values (V), Dates (D), Relationships (-), and Attributes (at) in two different written vestiges. Labels are indicated with this <symbol>. When a unit of information has different labels, they are separated by a comma. Example A1 is the written record of a vineyard purchase [58].

Example A1. _In nomine Domini. Ego <Ac1 Semplizia> et <Ac1-Ac2 sorori mea> nomine <Ac2 Cixolo>, nos simul in unum <Ac1-UT2, Ac2-UT2 uinditores> sumus tibi <Ac3 Guilara> <at-Ac3 presbiter> <Ac3-UT2 emptor>. Per hanc scriptura uindicionis nostre <UT1 uindimus> tibi <UT2 terra et uinea et arboribus et oliuaria>, hec omnia francum nostrum (pro)prium qui nobis aduenit, ad me <Ac1 Semplizia> per <Ac1-Ac* ienitores meos> et per compara et ad me <Ac2 Cixolo> per <Ac2-Ac* ienitores meos> et per ullasque uoces. Et est hec omnia in <UT3, UT3-UT4 comitatum Barquinona> infra <UT4, UT4-UT5 termine de Terracia> <UT5 in locum uocitatum Monte Agudo>. Afrontad <UT2 ipsa terra et uinea cum ipsos arboribus> qui ibi sunt fundatos <UT2-UT6, UT2-UT7 de oriente> in <UT6 aragallo> et in <UT7 terra> <Ac4-UT7, Ac5-UT7 de> <Ac4 Godmar> et <Ac5 suos eredes>, de <UT2-UT8 meridie> in <UT8 terra> <Ac6-UT8 de> <Ac6 Ego> <at-Ac6 femina>, <Ac6-Ac7 mulier de> <Ac7 Eruiio> <Ac8-UT8 et de> <Ac8 Guisado>, de <UT2-UT9, UT2-UT10 occiduo> in <UT9 uia> et in <UT10 terra> de <Ac3, AC3-UT10 te emptor>, de <UT2-UT11 circi> in <UT11 terra> de <Ac9, Ac9-UT11 Guisad>. Quantum istas afrontaciones includunt, sic uindimus tibi <UT2 ipsa terra el uinea et arboribus>, in ipso aragallo <UT12 ficulnea> I cum <UT13 pruneras> et <UT14 uides>, in alios locos prunera I et ficulneas II et <UT15 nogaria> et <UT16 pecera> et <UT17 glandifero> I et <UT18 oliuera> I ab integre cum exios et regresios earum ad tuum proprium propter precium <V1 solidos VI et denarios IIII ex moneda grossa>, quod manibus nostris accepimus et est manifestum, et de nostro iuro in tuo tradimus dominio et potestatem ad faciendum quod uolueris. Quod si nos uinditrices aut ullusque homo qui contra hanc ista carta uindicione uenerit pro inrumpendum aut nos uenerimus, non hoc ualead uindicare, set conponad aut conponamus tibi oc quod supra insertum est in duplo cum omnes illorum inmelioraciones, et in antea ista carta uindicione firma permanead omnique tempore._

Facta carta uindicione <D1 VI kalendas februarii anno XXII regnante Rodberto rege>.

<Ac1-UT19 Sig+num> <Ac1 Semplizia>. <Ac2-UT19 Sig+num> <Ac2 Cixolo>. Nos, qui hoc fecimus et firmare rogauimus. <Ac4-UT19 Sig+num> <Ac4 Godmar>. <Ac10-UT19 Sig+num> <Ac10 Mir>. <Ac11-UT19 Sig+num> <Ac11 Issarno>

SS. <Ac12 Ansemundo> <at-Ac12 presbiter> <Ac12-UT19 scripsit> cum literas superpositas in uerso V die et anno quod supra.

Example A2 is comprised of two consecutive paragraphs of a late medieval accounting book [59] (p. 298), property of merchant Joan de Torralba (Ac13). He registered the debts arising from the emission of letters of exchange, among many other transactions; in the Barcelonese headquarter of his company. The City of Barcelona is a previously known UT.

Example A2. _+ Ihesus + <D2 Mi CCCCXXXIIII. Divendres, a XXI de mag> (...) <UT20 Deuen> <Ac14 Anthoni de Paçi> e <Ac15 Francisco Tosingui> per <UT21 huna primera de cambi> de <Ac16 Còsimo> e <Ac17 Lorenço de Mèdici> feta en <UT22 Venècia> a <D3 XXIIII de abril>, <UT21 prometeren paguar> a <D4 LXV jorns ffeta> <V2 D ducats>, <UT23 rebuts> de <Ac18 Rubert Alibrandi> e <Ac19 Françesch Aloart>, que a rahó de <V3 XV sous V> fan a comte <V4 CCCLXXXV lliures VIII sous IIII>._

<D5 Dilluns, a XXIIII de mag>. <UT24 Deu> <Ac20 Johan Ventura> que m'acebtà <UT25 terza de cambi> de <Ac16 Còsimo> e <Ac17 Llorenço de Mèdici>, feta en <UT22 Venècia> a <D6 VIII d'abril>, <UT25

promes pagar> a <D7 LXV jorns feta> <V5 CC ducats>, a raó de <V3 XV sous V diners> per ducat, <UT26 rebuts> de <Ac18 Rubert Alibrandi> e <Ac19 Francesco Aloardi>, fan <V6 CLIIII lliures III sous IIII>.

Labeled data from both examples are included in a database. Main UT and Ac tables (Table A1 & Table A2) summarize the numbered observations identified for each class, and the relationships between both are shown as attributes of each. Table A1 shows Location and Date classes as attributes of the UT (See Figure 2 in the main text).

Table A1. Simplified UT dataset gathered from Examples A1 and A2.

Vestige	UT Id	UT Brief Description	Relationship(s)	Location	Biotic At	Anthropic At	Date
Example A1	01	Purchase	V1 (price)	= UT05		Fact, transaction	D1
Example A1	02	Land, vineyard, trees	Included in: UT05 Includes: UT12, 13, 14 Altered by UT01	= UT05		Property Activity: farming	D1
Example A1	03	County of Barcelona	Includes: UT04	Barcelona		Landscape: Place name	D1
Example A1	04	Municipality of Terrassa	Included in: UT03 Includes: UT05	Terrassa		Landscape: Place name	D1
Example A1	05	Place Montagut	Included in: UT04 Includes: UT2	UTM 31T x: 41582; y: 4599521		Landscape: Place name	D1
Example A1	06	Aregall	Delimitation (E): UT02	= UT04		Landsc.: Place name	D1
Example A1	07	Land	Delimitation (E): UT02 Owned by: Ac04, 05	= UT04		Property	D1
Example A1	08	Land	Delimitation (S): UT02 Owned by: Ac06	= UT04		Property	D1
Example A1	09	Via	Delimitation (W): UT02	= UT04		Road network: via	D1
Example A1	10	Land	Delimitation (W): UT02 Owned by: Ac03	= UT04		Property	D1
Example A1	11	Land	Delimitation (N): UT02 Owned by: Ac09	= UT04		Property	D1
Example A1	12	Fig trees	Altered by: UT01	= UT05	Flora, Fig	Activity: farming	D1
Example A1	13	Plum trees	Altered by: UT01	= UT05	Flora, Plum	Activity: farming	D1
Example A1	14	Vineyard	Altered by: UT01	= UT05	Flora, Vine	Activity: Wine prod.	D1
Example A1	15	Walnut trees	Altered by: UT01	= UT05	Flora, Walnut	Activity: farming	D1
Example A1	16	Fish farm	Altered by: UT01	= UT05	Fauna, Fish	Activity: fish farming	D1
Example A1	17	Acorn trees	Altered by: UT01	= UT05	Flora, Acorn	Activity: farming	D1
Example A1	18	Olive trees	Altered by: UT01	= UT05	Flora, Olive	Activity: Oil prod.	D1
Example A1	19	Purchase scripture	Altered by: UT01	= UT05		Activity: Scripture	D1
Example A2	20	Debt	Ac14&Ac15 to Ac13	= UT27		Activity: transaction	D2
Example A2	21	First letter of exchange	Ac14&Ac15 received from Ac16& Ac17	= UT22		Activity: transaction	D4
Example A2	22	Venice	Location UT21, 23, 25, 26	Venice		Activity: transaction	D3
Example A2	23	Loan	Ac18&Ac19 paid to Ac16& Ac17	= UT22		Activity: transaction	D3
Example A2	24	Debt	Ac20 to Ac13	= UT27		Activity: transaction	D5
Example A2	25	Third letter of exchange	Ac20 received from Ac16& Ac17	= UT22		Activity: transaction	D7
Example A2	26	Loan	Ac18&Ac19 paid to Ac16& Ac17	= UT22		Activity: transaction	D6
Example A2	27	City of Barcelona	Included in: UT03	Barcelona		Landscape: Place name	D2&D5

Table A2. Simplified Ac dataset gathered from Examples A1 and A2.

Vestige	Ac Id	Name	Job	Gender	Relationship(s)
Example A1	01	Semplizia	unknown	Female	Ac-UT: Seller UT02; Signature UT19/Ac-Ac: Sibling Ac02
Example A1	02	Cixolo	unknown	Female	Ac-UT: Seller UT02; Signature UT19/Ac-Ac: Sibling Ac01
Example A1	03	Guilara	Priest	Male	Ac-UT: Buyer UT02, Owner UT10
Example A1	04	Godmar	unknown	Male	Ac-UT: Owner UT07/Ac-Ac: Legacy to Ac05
Example A1	05	Godmar's Heirs	unknown		Ac-UT: Owner UT07/Ac-Ac: Heir of Ac04
Example A1	06	Ego	unknown	Female	Ac-UT: Owner UT09/Ac-Ac: Spouse Ac04
Example A1	07	Erviio	unknown	Male	Ac-Ac: Spouse Ac06
Example A1	08	Guisado	unknown	Male	Ac-UT: Owner UT09
Example A1	09	Guisad	unknown	Male	Ac-UT: Owner UT11
Example A1	10	Mir	unknown	Male	Ac-UT: Witness UT01, Signature UT19
Example A1	11	Issarno	unknown	Male	Ac-UT: Witness UT01, Signature UT19
Example A1	12	Ansemundo	Priest, Scribe	Male	Ac-UT: Scribe UT19
Example A2	13	Joan de Torralba	Boss Merchant	Male	Ac-UT: Indebted UT20, 24
Example A2	14	Antonio de Pazzi	Merchant	Male	AC-UT: Debtor UT20, Indebted UT21
Example A2	15	Francesco Tosinghi	Merchant	Male	AC-UT: Debtor UT20, Indebted UT21
Example A2	16	Cosme de Medici	Banker	Male	AC-UT: Debtor UT21, 25; Paid UT23, 26
Example A2	17	Lorenzo de Medici	Banker	Male	AC-UT: Debtor UT21, 25; Paid UT23, 26
Example A2	18	Roberto Aldobrandi	Merchant	Male	AC-UT: Payer UT23, 26
Example A2	19	Francesc Alvart	Merchant	Male	AC-UT: Payer UT23, 26
Example A2	20	Giovanni Ventura	Merchant	Male	AC-UT: Debtor UT24, Indebted UT25

When UT, Ac, and their relations are properly identified, data exploitation and visualization have a great potential. Table A3 is a specific exploited dataset arising from Example A2. In this kind of documentation, economic relations are far more important than any other relationship and most of the texts follow the same template and record similar activities. Hence, transactions are a specific kind of UT in which two or more Ac are related through money exchange, usually using different coins. Within this table, only transaction UT are shown with all the relations implied.

Table A3. Specific transaction dataset built upon the relationship between Actors, UT, Date, and Values obtained from Example A2.

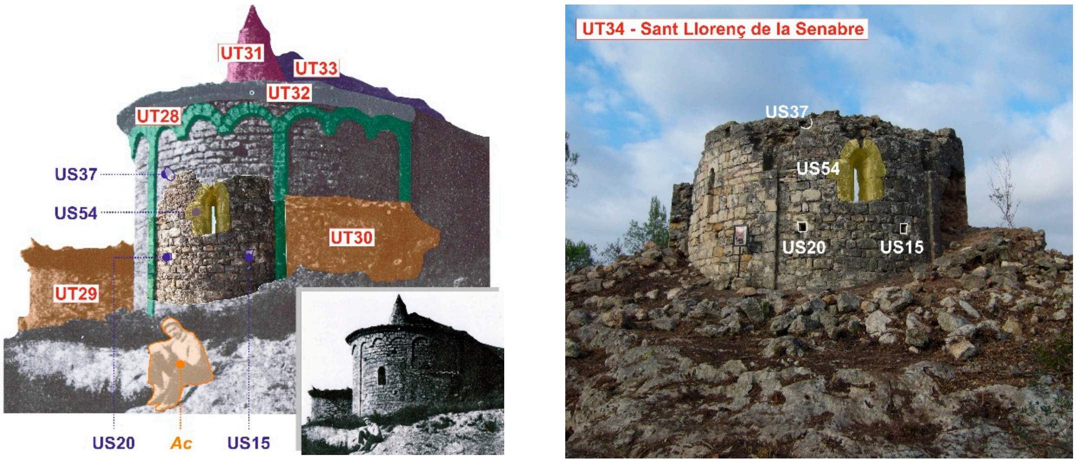
Type	Date	Active Ac	Object	Passive Ac	Price	Location
UT20 - Debt	D2 - 1434/05/21	Ac14 - A. de Pazzi	UT21	Ac13 - J. Torralba	V4 - 385lb 8sb 4db*	UT27 - Barcelona
UT20 - Debt	D2 - 1434/05/21	Ac15 - F. Tosinghi	UT21	Ac13 - J. Torralba	V4 - 385lb 8sb 4db	UT27 - Barcelona
UT21 - Letter	D4 - 1434/06/29	Ac16 - C. Medici	none	Ac14 - A. de Pazzi	V2 - 500 du.	UT22 - Venice
UT21 - Letter	D4 - 1434/06/29	Ac17 - L. Medici	none	Ac15 - F. Tosinghi	V2 - 500 du.	UT22 - Venice
UT21 - Letter	D4 - 1434/06/29	Ac17 - L. Medici	none	Ac14 - A. de Pazzi	V2 - 500 du.	UT22 - Venice
UT21 - Letter	D4 - 1434/06/29	Ac16 - C. Medici	none	Ac15 - F. Tosinghi	V2 - 500 du.	UT22 - Venice
UT23 - Loan	D3 - 1434/04/24	Ac18 - R. Aldobrandi	UT21	Ac17 - L. Medici	V2 - 500 du.	UT22 - Venice
UT23 - Loan	D3 - 1434/04/24	Ac18 - R. Aldobrandi	UT21	Ac16 - C. Medici	V2 - 500 du.	UT22 - Venice
UT23 - Loan	D3 - 1434/04/24	Ac19 - F. Alvart	UT21	Ac16 - C. Medici	V2 - 500 du.	UT22 - Venice
UT23 - Loan	D3 - 1434/04/24	Ac19 - F. Alvart	UT21	Ac17 - L. Medici	V2 - 500 du.	UT22 - Venice
UT24 - Debt	D5 - 1434/05/24	Ac20 - G. Ventura	UT25	Ac13 - J. Torralba	V6 - 154lb 3sb 4db	UT27 - Barcelona
UT25 - Letter	D7 - 1434/08/18	Ac16 - C. Medici	none	Ac20 - G. Ventura	V5 - 200 du.	UT22 - Venice
UT25 - Letter	D7 - 1434/08/18	Ac17 - L. Medici	none	Ac20 - G. Ventura	V5 - 200 du.	UT22 - Venice
UT26 - Loan	D6 - 1434/04/08	Ac18 - R. Aldobrandi	UT25	Ac17 - L. Medici	V5 - 200 du.	UT22 - Venice
UT26 - Loan	D6 - 1434/04/08	Ac18 - R. Aldobrandi	UT25	Ac16 - C. Medici	V5 - 200 du.	UT22 - Venice
UT26 - Loan	D6 - 1434/04/08	Ac19 - F. Alvart	UT25	Ac16 - C. Medici	V5 - 200 du.	UT22 - Venice
UT26 - Loan	D6 - 1434/04/08	Ac19 - F. Alvart	UT25	Ac17 - L. Medici	V5 - 200 du.	UT22 - Venice

* Notice that V3 is an exchange value, and that V2 $*$ V3 = V4, and V5 $*$ V3 = V6.

Appendix B

Data labeling is only possible in written sources. These might be the richer ones in Actor, Value, or absolute Date information. Notwithstanding this fact, Units of Topography as evidences of events are available and identifiable in many other material and non-material vestiges. This appendix provides examples of graphic vestiges and their subsequent UT identification.

Example A3. *Is a picture [60] of Sant Llorenç de la Senabre (Santa Margarida i els Monjos, Barcelona, Spain), a Romanesque church reused as a farm in the 19th Century AD. This picture in Figure A1a was taken in 1912 prior to the collapse and abandonment of the structure. As a vestige, it was a valuable source of data to interpret the later vestiges in 2011 and the following years, when the archaeological record was built. Figure A1b illustrates* *the identification of US during the archaeological survey in 2011. The north side of the apse was transformed into a domestic oven. This hypothesis that arose from the survey was confirmed during the excavation in 2012, and the oven was later restored in 2016. Figure A2 illustrates the fieldwork results.*



(**a**) (**b**)

Figure A1. Sant Llorenç de la Senabre in 1912 (**a**) and 2011 (**b**). UT and US are identified through image processing and illustration software. US identification is possible in vestiges remaining in the present. Disappeared walls and annex structures have to be considered as UT.

(**a**) (**b**)

Figure A2. Sant Llorenç de la Senabre's domestic oven after the completion of the excavation in 2012 (**a**) and its restoration in 2016 (**b**).

Example A4. *Is a drawing from the 17th Century AD that illustrates the town of Martorell watched from the west side of river Anoia. The artist—Pier Maria Baldi—illustrated in watercolor some elements of the material heritage currently disappeared during a journey along Spain and Portugal that he made in Cosme de Medici's company [61]. Figure A3 shows the original picture together with a labeled version of it.*

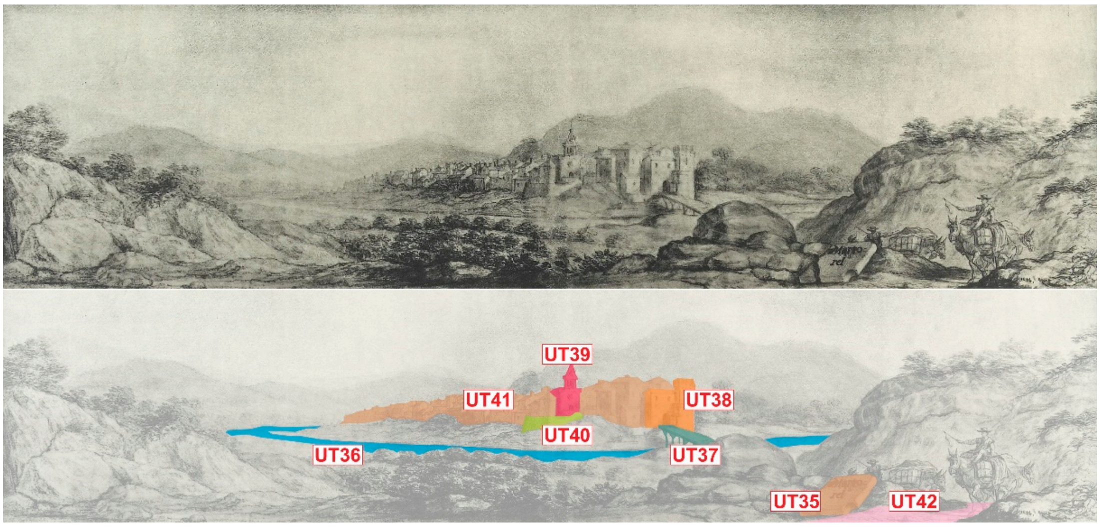
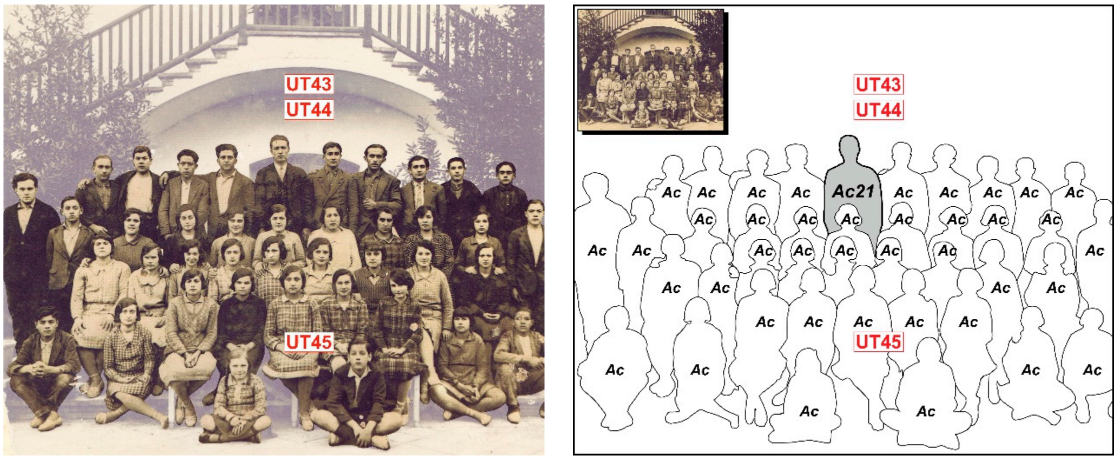


Figure A3. Pier Maria Baldi's drawing of Martorell in the 17th Century <UT. UT are identified and labeled accordingly.

Example A5. *Is a protograph of schoolchildren and their teacher [62]. This kind of pictures usually inform about several UT and Ac, though the analyst is not always able to identify all the actors or places represented. We could only identify the teacher in this example, despite many other actors being present. Figure A4 shows UT and Ac labelling on the picture.*



(**a**) (**b**)

Figure A4. Schoolchildren from the Company Guarro Casas' School, taken in Gelida (Catalonia, Spain) in 1927. UT are labeled directly onto the picture (**a**) while Ac are labeled in a separate sketch for the sake of clarity (**b**). We edited the original picture by means of image processing and illustration software.

According to the examples in Appendix B, a summary dataset obtained from UT and Ac identification on graphic vestiges are provided in Tables A4 and A5. Actor identification is not possible in Example A3.

Table A4. Simplified UT dataset gathered from Examples A3, A4, and A5.

Vestige	UT Id	UT Brief Description	Relationship(s)	Location	Biotic At	Anthropic Attributes	Date
Example A3	28	Lombard bands	Attached to UT34	= UT34		Construction: Decoration	1912 AD
Example A3	29	Annexe building	Attached to UT34	= UT34		Construction: Structure	1912 AD
Example A3	30	Annexe building: Domestic oven	Attached to UT34	= UT34		Construction: Structure	1912 AD
Example A3	31	Chimney	Affects UT34	= UT34		Construction: Structure	1912 AD
Example A3	32	Apse roof	Onto UT34	= UT34		Construction: Structure	1912 AD
Example A3	33	Nave roof	Onto UT34	= UT34		Construction: Structure	1912 AD
Example A3	34	Sant Llorenç de la Senabre Romanesque church	Beneath: UT32, 33 Affected by: UT34 UT28, 29, 30 are attached	Santa Margarida i els Monjos (Barcelona, Spain)		Construction: Structure	11th Cent AD
Example A4	35	Martorell	Includes: UT37, 38, 39, 40, 41	Martorell (Catalonia, Spain)		Landscape: Place name	1668 AD
Example A4	36	River Anoia	Passes by: UT35	= UT35	Watercourse		1668 AD
Example A4	37	Bridge on the river Anoia	Affects: UT36 Included in: UT35	= UT35		Construction: Structure	1668 AD
Example A4	38	Anoia's Gate	Included in: UT35	= UT35		Construction: Structure	1668 AD
Example A4	39	Church of Saint Mary	Included in: UT35	= UT35		Construction: Structure	1668 AD
Example A4	40	Medieval Wall	Included in: UT35	= UT35		Construction: Structure	1668 AD
Example A4	41	Town Buildings	Included in: UT35	= UT35		Construction: Structure	1668 AD
Example A4	42	Royal Pathway	Passes by: UT35	= UT35		Landscape: Road	1668 AD
Example A5	43	Company Guarro Casas' School	Included in: UT47 Includes: UT45 Linked to: UT44, UT46 Engaged Ac21	= UT47		Activity: teaching	1927 AD
Example A5	44	Old Mill Building	Linked to: UT43	= UT47		Construction: Structure	1927 AD
Example A5	45	Teaching course	Included in: UT43 Performed by Ac21	= UT47		Activity: teaching	1927 AD
Example A5	46	Company Guarro Casas	Linked to: UT43	= UT47		Activity: paper production	1927 AD
Example A5	47	Gelida	Includes: UT43	Gelida (Catalonia, Spain)		Landscape: Place name	1927 AD

Table A5. Simplified Ac dataset gathered from Examples A3, A4, and A5.

Vestige	Ac Id	Name	Job	Gender	Relationship(s)
Example A3	-	unknown	unknown	Male	unknown
Example A5	21	Josep Maria Roig	School teacher	Male	Ac-UT: Performs UT45; Ac-Ac: Teaches unknown Ac
Example A5	-	unknown	unknown	Male	Ac-UT: Attends to UT45; Ac-Ac: Student of Ac21
Example A5	-	unknown	unknown	Female	Ac-UT: Attends to UT45; Ac-Ac: Student of Ac21

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